An LTI control toolbox – simplifying feedback controller design

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1 Abstract

Throughout the years, the study of feedback control has yielded a variety of design techniques. Although control engineers stick to classical open loop shaping, modern techniques gain relevance as they provide the means to push performance to the limit while taking uncertainty into account. The $\mathscr{H}_\infty$ design framework [1] is a modern approach which takes objectives and constraints rigorously into account. However, practical difficulties are still overruling their benefits, sustaining the dominance of standard PID control.
In order to ease $\mathscr{H}_\infty$ controller design, we are developing a Matlab LTI Control Toolbox[1] that provides the means to do a state-of-the-art controller design. It provides an interface to specify the control configuration and a set of requirements. Unstable and improper weighting functions are allowed, reducing the amount of post-processing. The following paragraphs show how to use this LTI toolbox.

2 Control configuration

The control configuration incorporates the connections between all dynamic systems. As an example, the plant in Fig. 1 is described by Code example 1.
In order to make systems G and S available to the toolbox, they are declared as an *LTIsys*. Their inputs and outputs can then be assigned to a new convenience variable, e.g. '$u = G.in$', or connected to eachother, e.g. '$S.in == y$'.

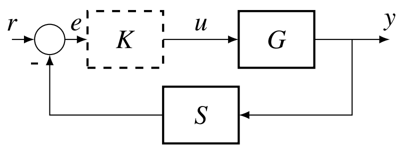

Figure 1: Representation of a control configuration. G and S are dynamic systems which make up the plant. K indicates the controller which eventually closes the loop.

```
G = LTIsys(G); %make G.in and G.out available
S = LTIsys(S);

lti_begin()
    signal r            %declare the reference

    u = G.in;           %define u as G's input
    y = G.out;          %define y as G's output
    e = r - S.out;      %define the error
    S.in == y;          %connect S to G
    K.in = e;           %set controller input
    K.out = u;          %set controller output
lti_end
```

Code example 1: LTI control toolbox code to describe the control configuration depicted in Figure 1.

3 Control requirements

The control requirements are formulated as a set of objectives and constraints. These usually consist of some target closed-loop transfer function, multiplied by some frequency dependent weight.
As an example, consider the problem of a servo mechanism with a fixed required bandwidth. This translates to a constraint on the sensitivity, $r \to e$ (2). Also robustness can be maximized (1), leading to the next optimization problem:

$$\underset{K}{\text{minimize}} \left\| W_T \frac{y}{r} \right\|_\infty \tag{1}$$

$$\text{subject to} \left\| W_S \frac{e}{r} \right\|_\infty \leqslant 1 \tag{2}$$

```
WT = Weight.HF(10,2);
WS = Weight.LF(1,1);

lti_begin()
    %% ... %% plant declaration

    ctrl_begin('my_controller')
        minimize(WT*(y/r))
        subject to
            WS*(e/r) <= 1
    ctrl_end
lti_end
```

Code example 2: LTI control toolbox code to design the controller as described by problem (1)-(2).

References

[1] C. Scherer, P. Gahinet and M. Chilali, "Multiobjective output-feedback control via LMI optimization," Automatic Control, IEEE Transactions on, Vol. 42, 7, 896–911, 1997.

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[1] The developed LTI control toolbox is freely available on github: https://github.com/maartenverbandt/lti_toolbox